Characterization of Cs-137 Beam for Calibration and Dosimetric Applications

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***Abstract*- In this work, characterization of radiation beam of ^{137}Cs source was performed for calibration and dosimetric purposes at National institute for standards (NIS). Different thickness of lead sheets was used to attenuate the beam in order to cover all scales of radiation detectors under calibration. The air Kerma rate was measured with two ion chambers PTW 30013 and M-32002 for both direct and attenuated beam respectively. Scattering contribution and beam flatness were measured and took into consideration in the uncertainty budget calculations. Energy spectra for direct and attenuated ^{137}Cs photon beams were measured by Sodium iodide gamma spectrometer. This work shows that the used lead attenuators enabled the calibration of all ranges of air kerma rate which are needed to be covered for radiation protection dose level. Also the use of lead collimator at 15^{o} angle reduces the scattering by 12% at two meter distance.**

Keywords- Cs-137; Calibration; Dosimetry; Scattering and Uncertainty

I. INTRODUCTION

National Metrology Institutes (NMIs) are responsible to provide traceability to SI units for the radiation measurements within the country at all levels such as radiation protection level. These NMIs include reference radiation gamma ray facilities which are needed to be characterized in terms of air Kerma using suitable standard dosimetry systems [1, 4]. Also the Ionizing Radiation Metrology Lab (IRML) is one of the Secondary Standard Dosimetry Lab (SSDL) of the IAEA and WHO network.

The ^{137}Cs reference beam at the National Institute for standards (NIS) is characterized to be used in survey meter calibrations and other radiation detectors at protection level. The used Secondary standard ionization chambers are traceable to the SI units provided by BIPM, Paris. Cs-137 high dose rate enforces the need of lead attenuators in order to cover the range of protection level calibrations. So characterization and setting up of the Cs-137 irradiation facility is needed to facilitate its use in calibration purposes. And the attenuation of such beam is needed. The Cs-137 irradiation facility as shown in Fig. 1 include cylindrical shield with rectangular window for exposure. Holders of steel were designed and constructed to hold lead sheets for attenuation in front of the exposure window.

II. MATERIAL AND METHODS

Kerma dose rate of the Cs-137 was measured using PTW secondary standard dosimetry system which was composed of Unidos electrometer and two ion chambers (PTW 30013 and M-32002). The first chamber was used for measuring the Cs-137 direct beam, while the second was used for measuring the attenuated beam at different distances from the source. Spectroscopy of the beam after attenuation was performed using sodium iodide crystal attached to the Nomad analyzer (gamma spectrometer) [2, 5].

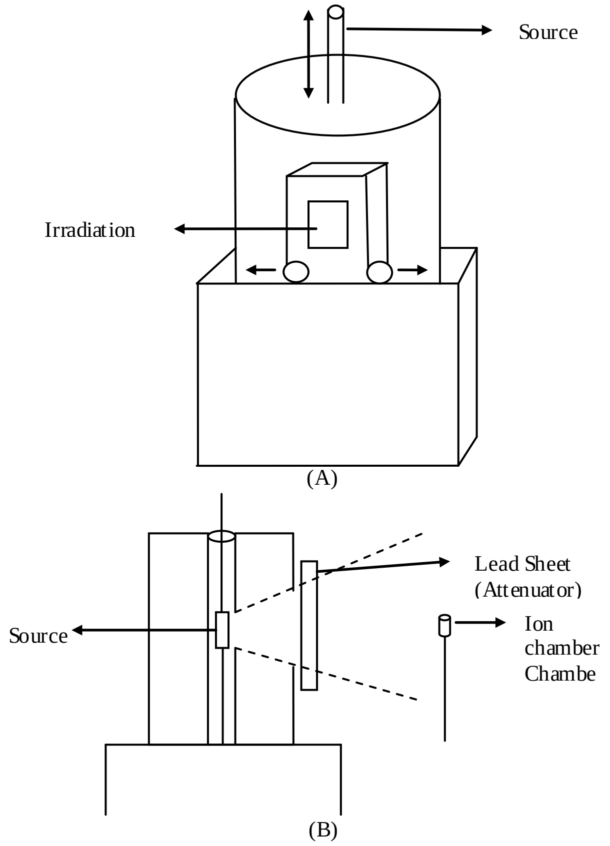

Fig. 1 The Cs-137 irradiation facility at NIS: (A) Longitudinal view; (B) Lateral view

III. RESULTS AND DISCUSSION

A. *Dosimetry of Cs -137 Beam*

The kerma dose rate from Cs-137 at different Source to chamber central electrode distances SCD was measured for the direct and attenuated beam with three different thicknesses of lead and represented in Fig. 2.

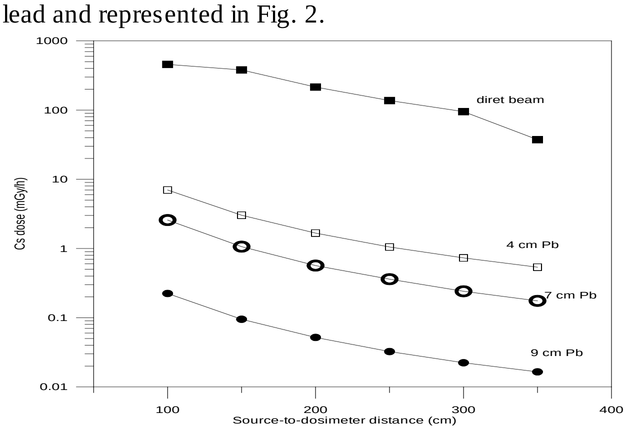

Fig. 2 Cs-137 Kerma dose rate with different SCD's

Fig. 2 shows that the use of lead thickness up to 9 cm reduces the Cs-137 kerma dose rate from 500 to 0.01 mGy/h, i.e., about 4 different order of magnitude of Kerma rate. Therefore almost all of the radiation measuring instrument scales could be calibrated.

B. *Energy Characterizations*

To study the energy characterization for the beam before and after attenuation, photon spectroscopy was performed by gamma spectrometer. Fig. 3 shows the spectrum of direct Cs-137 beam from point source as well as the attenuated ones. This figure shows that the energy of the Cs-137 beam is the same (within the spectrometer resolution) for both direct and the attenuated beam except for that of 4 cm Pb. This may be attributed to the high activity of Cs-137 source and the high dead time of the spectrometer.

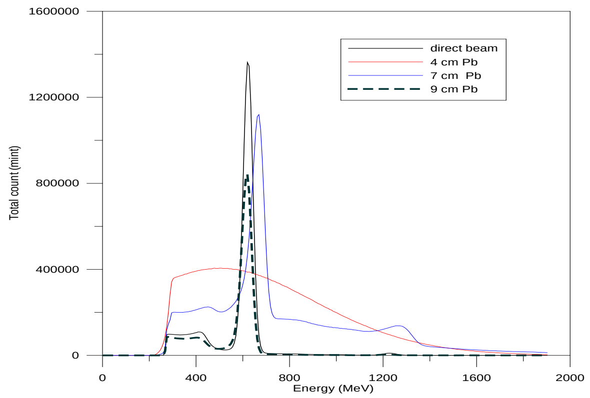

Fig. 3 Spectra of direct and attenuated beam of Cs-137

C. *Scattering Contribution Estimation*

To measure the scattering contribution due to attenuator, several methods like shield and room walls could be used. In this work a lead collimator with angle of 15^o was used. The scattering contribution is calculated from the ratio between the dosimeter reading with and without the collimators. Data of the scattering contribution is represented in Fig. 4. This figure shows that, the scattering increases with increase in distance up to 2 m between source and dosimeter and then it has a constant value. This may be attributed to the width of the irradiation room is 4m and the source is situated in the center i.e. 2m from the wall, hence the maximum value of scattering is at 2m and then has a constant value.

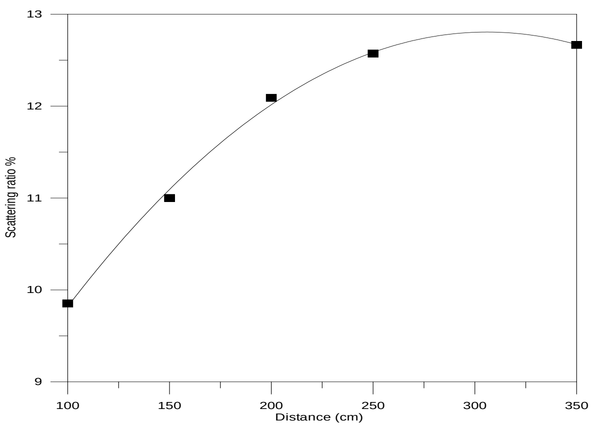

Fig. 4 Scattering contribution with different distances

D. *Beam flatness*

At the distance of two meter from the source, the 137Cs Kerma rate was measured at different lateral distances to study the beam flatness (Fig. 5) for both direct and the attenuated beam. Fig. 5 shows that the attenuated beam has more flatness than the direct one, which indicates that the attenuated beam is homogeneous enough to be used in calibration of any instrument with different dimensions.

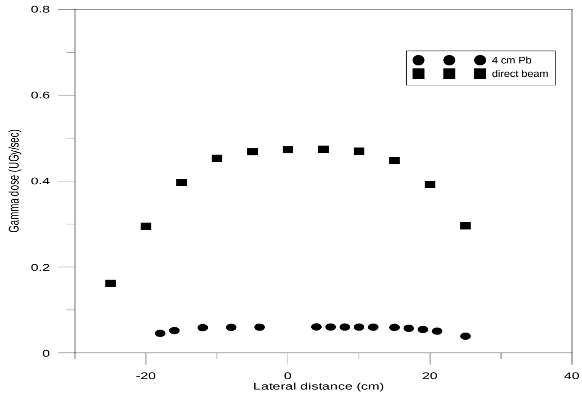

Fig. 5 Beam flatness at different lateral distances

E. *Uncertainty Calculations*

Different sources of uncertainty are considered in this study such as calibration factors of dosimetry system, environmental conditions, resolution of instruments and other factors (see Table I). The most important factor affecting the overall uncertainty is the scattering contribution, which can be attributed to the lead used for both attenuation and shielding purposes [6]. The uncertainty budget of the Cs-137 beam Kerma rate is represented in Table I.

TABLE I UNCERTAINTY BUDGET OF AIR KERMA RATE FOR THE CS-137 IRRADIATION FACILITY

Parameter/unit	s_i (Type A) %	u_i (Type B) %
Air kerma rate of Cs-137		
Repeatability of Measurement	0.35	
Reproducibility of Measurements	0.4	0
N_k of Secondary Standard	0	0.1
Ionization Current of the Secondary Standard	0.01	0.0067
Scattering Contribution	0.35	1
TPH Correction	0.35	0.18
Leakage Current	0.1	0.1
Radial Non-uniformity	0.2	0.2
Recombination	0.1	0.1
Distance	0.2	0.5
Quadratic Summation	0.6276	1.352445
Combined Relative Standard Uncertainty	1.41	

The expanded uncertainty of output air kerma of Cs-137 source is 2.82 % with coverage factor of 2 and confidence level 95%.

IV. CONCLUSION

This work shows that the used lead sheets reduce the Kerma rate of Cs-137 by four orders of magnitude to cover all scales of radiation measuring instrument needed to be calibrated at NIS. Using a collimator with solid angle of 15o reduces the room scattering by about 12 % at distance of two meter from the source. Cs-137 energy is nearly the same with the use of lead sheets for attenuation, while Beam flatness is improved at attenuated beam. After these characterizations, our SSDL has participated in inter comparison audit program

using TLD with the IAEA in the protection level (5 mGy) and the degree of agreement of the results is improved at 2.4 %, which is within the limit of uncertainty.

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